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Diversity of the riparian vegetation of high Andean wetlands of the Junín region, Peru

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ABSTRACT

The diversity of the riparian vegetation of five high Andean lagoons of the Junin region was evaluated between March and December of 2017. The sampling of the riparian vegetation was carried out by means of the transect method. The unidentified species were collected for later identification in the herbarium. The diversity was determined by floristic composition, abundance and frequency, and by species richness indices of Simpson and Shannon-Wiener. In the Pomacocha Lagoon, the floristic composition was represented by 43 species, distributed in 15 families, with the most abundant species being *Aciachne pulvinata*, *Azorella crenata* and *Geranium sessiliflorum* and the most frequent *Aciachne pulvinata.* In the Laguna Tragadero, the floristic composition was represented by 17 species, distributed in 10 families, with the most abundant species being *Pennisetum clandestinum and Eleocharis sp* and the most frequent *Polypogon interruptus*. In the Cucancocha Lagoon, the floristic composition was represented by 19 species, distributed in 7 families, with the most abundant species being *Calamagrostis sp* and *Wernberia humbellata* and the one of most frequent *Carex ecuadorica*. In the Incacocha Lagoon, the floristic composition was represented by 22 species, distributed in 11 families, with the most abundant and frequent species being *Alchemilla pinnata*. In the Ñahuinpuquio Lagoon, the floristic composition was represented by 20 species, distributed in 9 families, with the most abundant species being *Pennisetum clandestinum* and the most frequent species *Pennisetum clandestinum, Juncus arcticus* and *Muhlenbergia andina*. The results obtained contribute data on the diversity of riparian vegetation of high Andean wetlands in the Junin region, Peru.

Keywords: biodiversity indexes, floristic composition, high Andean wetlands, riparian vegetation.

Diversidade da vegetação ripária das áreas alagadas andinas altas na região de Junín, Peru

RESUMO

Avaliou-se a diversidade da vegetação ripária de cinco lagos altos andinos da região de Junin entre março e dezembro de 2017. A amostragem da vegetação ripária foi realizada por meio do método de transectos. As espécies não identificadas foram coletadas para posterior identificação no herbário. A diversidade foi determinada pela composição florística, abundância e frequência e pelos índices de riqueza de espécies, Simpson e Shannon-Wiener. Na lagoa Pomacocha a composição florística foi representada por 43 espécies, distribuídas em 15 famílias, as espécies mais abundantes foram *Aciachne pulvinata*, *Azorella crenata* e *Geranium sessiliflorum* e a mais frequente *Aciachne pulvinata*. Na lagoa Tragadero a composição florística foi representada por 17 espécies, distribuídas em 10 famílias, as espécies mais abundantes foram *Pennisetum clandestinum* e *Eleocharis sp* e a mais frequente *Polypogon interruptus*. Na lagoa Cucancocha a composição florística foi representada por 19 espécies, distribuídos em 7 famílias, as espécies mais abundantes foram *Calamagrostis sp* e *Wernberia humbellata* e a mais frequente *Carex ecuadorica*. Na lagoa Incacocha a composição florística foi representada por 22 espécies, distribuídas em 11 famílias, sendo a espécie mais abundante e freqüente *Alchemilla pinnata*. Na lagoa Ñahuinpuquio a composição florística foi representada por 20 espécies em 9 famílias, sendo a espécie mais abundante *Pennisetum clandestinum* e as espécies mais freqüentes *Pennisetum clandestinum*, *Juncus articus* e *Muhlenbergia andina*. Os resultados obtidos contribuem com dados sobre a diversidade da vegetação ripária das áreas úmidas andinas da região de Junin, no Peru.

Palavras-chave: altiplano andino alto, composição florística, índices alfa-biodiversidade, vegetação ripária.

1. INTRODUCTION

The high Andean wetlands play a vital role in the development of the Andean basins, as well as other hydrographic systems, since their waters flow towards the slopes of the Amazon and towards the coasts of the Pacific and the Caribbean. These wetlands and wetland complexes maintain a unique biological diversity and are characterized by a high level of endemism of plants and animals. In addition, they are fundamental components of the habitat of species of notable economic and ecological importance such as the vicuña, the guanaco or the chinchilla, among others (Ramsar, 2005). High Andean wetlands are ecosystems that include a wide variety of environments, which share as a fundamental characteristic the presence of water. They have a unique biological diversity and are considered ecosystems of great fragility (Gonzales, 2015) due to natural (extreme conditions) and anthropogenic pressures (unsustainable agriculture, overgrazing and unsustainable mining in the páramo and puna). Understanding of the importance of biodiversity has developed over the years that followed the report of the World Commission on Environment and Development (Brundtland Report). It is increasingly recognized that human beings are part of the ecosystems in which they live, that they are not an independent part of them and that they are affected by changes in these ecosystems (Ash and Fazel, 2007).

It is estimated that the diversity of plant species and their distribution in space have important effects on the function of wetland ecosystems. However, knowledge of the relationships between plant species and spatial diversity remains incomplete (Brandt *et al.*, 2015).

Studies of wetlands in Western Europe and other terrestrial ecosystems in North America often show that nutrient enrichment causes changes in the composition of the species, decrease in the diversity of plant species in general and loss of rare species and uncommon ones (Bedford *et al.*, 1999).

The Andes are the richest center of species biodiversity in the world. Most of the conservation research and attention in the Andes has focused on biomes such as rainforest, cloud forest and paramo, where the diversity of plant species is the result of the rapid speciation associated with the recent Andean orogeny (Pennington *et al.*, 2010).

Peru is one of the most valuable countries on our planet, due to its high ecological diversity of climates, altitudinal band of vegetation and productive ecosystems. The high diversity of ecosystems has allowed the development of numerous human groups (Brack, 2014). However, the high Andean continental aquatic ecosystems are still the least studied and represent one of the most-threatened and least-managed systems (Acosta, 2009).

There are initiatives by different governmental and non-governmental organizations to inventory biological resources, including the National Service of Natural Protected Areas of Peru, national universities and NGOs. However, these initiatives are scattered; there is no coordination between them and existing studies are scarce.

Studies have been carried out on the Poaceae in the Huancavelica-Peru region, such as the works of Tovar (1957, 1960, 1965 and 1972) in the provinces of Huancavelica, Tayacaja and Castrovirreyna (Gutiérrez Peralta and Castañeda Sifuentes, 2014). However the information on the diversity of the riparian vegetation of high Andean wetlands of the Junín region is scarce; becoming one of the first research works at the regional level.

The definition of the diversity of species considers both the number of species and the number of individuals (abundance of each species existing in a certain place). It is evaluated by means of indices, which are tools used in floristic and ecological studies to compare the diversity of species, whether between habitat types, forest types, etc. (Mostacedo and Fredericksen, 2000), the Andes being the richest biodiversity point of species in the world (Pennington *et al.*, 2010). In this sense, it is necessary to carry out inventories of riparian vegetation to understand the diversity and the state of conservation in which they are found in order to complement the efforts to reduce the uncertainty about the knowledge of biodiversity in these ecosystems. Therefore, the objective of the study was to evaluate the diversity of riparian vegetation of five high Andean wetlands of the Junín region.

2. MATERIAL AND METHODS

2.1. Study area

The study area included five high Andean lagoons located in the Junín region, in Peru, which present regular riverine vegetation, around which extensive cattle ranching (sheep, bovine and camelids) is developed. The Pomacocha lagoon is located in the district of Apata, Concepción province at 4486 masl (473139 E, 8697593 N). The Tragadero lagoon in the district of Paca, province of Jauja at 3465 masl (441171 E, 8699215 N). The Cucancocha lagoon in the district of San José de Quero, Chupaca province at 4481 masl (488791 E, 8668186 N). The Incacocha lagoon in the district of Yanacancha, Chupaca province at 4420 masl (417825 E, 8669695 N). The Ñahuinpuquio in the district of Ahuac, Chupaca province at 3372 masl (463131 E, 8665631 N). (Figure 1).

The productive activities of the high Andean wetlands are associated with the altitude in which they are located. In the areas of the puna, jalca and paramo, the predominant activities are livestock of cattle, sheep and camelids, mining, fishing and industrial afforestation. Subsistence activity is the extraction of plants and peat as fuel, since in many areas a good part of the rural population depends on firewood to cook their food. At lower altitudes, crops of potatoes and other tubers and Andean cereals are produced. Extensive cattle ranching is favored in the high Andean wetlands because they are associated with the generation of fodder for wild and domesticated species such as alpacas, lamas, goats, sheep and cattle (Ramsar, 2005).

2.2. Methods

The sampling stations were selected according to the morphometry of the water bodies. Four samplings were carried out in April, May, September and October of 2017. The sampling method applied in each of the stations was the transect method, because it is a very used method to inventory and evaluate grasslands, especially pastures, due to its advantages over the method of plots with fixed dimensions, mainly because it is fast and allows to capture greater variability in the terrain and therefore the dispersion of the species. Each registration point was defined by a survey ring 2.5 cm in diameter, held by a 60 cm long bronze rod (Flórez, 2005).

The diversity of the riparian vegetation was determined by the floristic composition, abundance and frequency, according to the guide of evaluation of the wild flora of the MINAM (Perú, 2011) and through the indices of species richness of Simpson and by Shannon-Wiener.

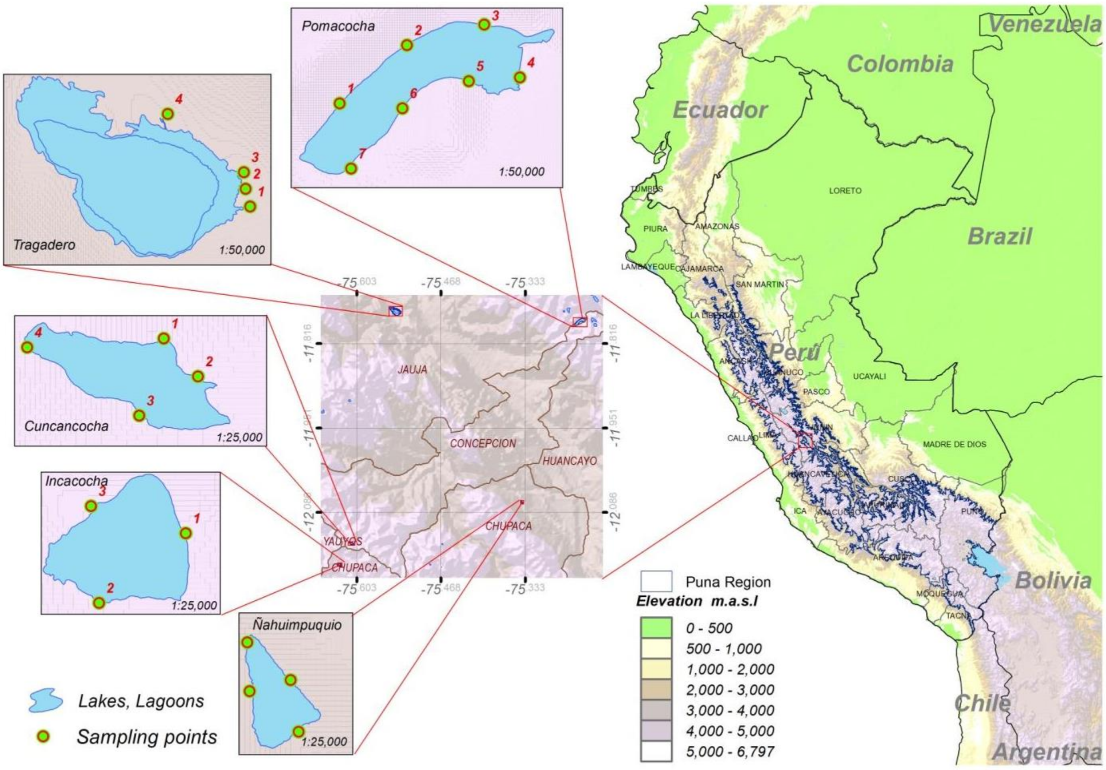

Figure 1. Location of the high Andean lagoons of the Junín region – Peru.

The floristic composition is the list of species registered in the totality of samples raised. The absolute abundance is the number of individuals of each species existing in a certain type of vegetation or area and relative abundance is expressed as a percentage of the total number of individuals. The absolute frequency is the number of times that a species is present in the total of sampling points raised and relative frequency is expressed as a percentage of the total number of sampling points surveyed.

The index of species richness (S) is the simplest way to measure biodiversity, since it is based solely on the number of species present, without taking into account the value of importance of them.

The Simpson Index is an index based on dominance; it is a reverse parameter to the concept of uniformity or equity of the community. It takes into account the representativeness of the species with greater importance value without evaluating the contribution of the rest of the species.

Carr *et al.* (2007) cited in Moreno (2001) state that the Simpson index is a measure of dominance that is strongly influenced by the importance of the most dominant species, and as the index increases, the diversity decreases; that is, when this probability is higher, less diverse is the plant community. That's why the Simpson index has the tendency to be smaller when the community is more diverse. Its formula is (Equation 1):

$$D_{Si} = \frac{\sum_{i=1}^{S} n(n-1)}{N\,(N-1)} \quad (1)$$

The Shannon-Wiener Index is the most-recognized index that is based mainly on the concept of equity.

Mayr (1992) mentions that the Shannon-Wiener Index expresses the uniformity of values of importance across all species in the sample. Acquire values between zero, when there is only one species, and the logarithm of S, when all species are represented by the same number of individuals (Magurran, 1988, cited in Moreno 2001). This index requires that all species are represented in the sample and is very susceptible to abundance; normally it takes values between 1 and 4.5. Values above 3 are typically interpreted as diverse (Barajas-Gea, 2005). Its formula is (Equation 2):

$$H' = -\Sigma \text{ pi x ln pi} \quad (2)$$

The data of abundance, frequency and alpha diversity indices of species richness, Simpson and Shannon-Wiener, were analyzed through the statistical program Past 3.17.

3. RESULTS AND DISCUSSION

3.1. Floristic composition, abundance and frequency of the Pomacocha Lagoon

The floristic composition was represented by 43 species identified in the riparian vegetation of the Pomacocha Lagoon, distributed in 15 families. The most representative families are Poaceae and Asteraceae with 9 species each, followed by Cyperaceae (4), Plantaginaceae (3), Caryophyllaceae (3), Apiaceae (3), Geraniaceae (2), Ranunculaceae (2), Gentianaceae (2), Rosaceae (1), Isoetaceae (1), Polygonaceae (1), Fabaceae (1), Oxalidaceae (1) and Juncaceae (1).

The most abundant species are *Aciachne pulvinata*, *Azorella crenata and Geranium sessiliflorum*, representing 15.90%, 8.92% and 8.79%, respectively. The less abundant species are *Eleocharis sp* and *Luzula racemosa*, where each species represents 0.13%.

The species with more frequency is *Aciachne pulvinata*, which represents 8.05%. This species has characteristics adapted to the environment and is frequent in the lagoon of Pomacocha. There are several less frequent species, possibly due to the demand of environmental factors, among which are *Geranium weddelli, Oreithales sp, Dactilis glomerata*, among others, where each species represents 1.15% (Table 1).

3.2. Floristic composition, abundance and frequency of the Tragadero Lagoon

The floristic composition consisted of 17 identified species in the riparian vegetation of the Tragadero Lagoon, distributed in 10 families. The most representative families are Asteraceae and Fabaceae with 3 species each, followed by Apiaceae (2), Cyperaceae (2), Poaceae (2), Rosaceae (1) Juncaceae (1), Oxalidaceae (1), Caryophyllaceae (1) and Gentianaceae (1).

The most abundant species are *Pennisetum clandestinum* and *Eleocharis sp*, representing 38.46% and 20.36%. The least abundant species are *Oxalis sp* and Polypogon *interruptu*s, which represent 0.11%.

Table 1. Floristic composition, abundance and frequency of the Pomacocha Lagoon.

Floristic Composition		Absolute Abundance	Relative Abundance (%)	Absolute Frequency	Relative Frequency (%)
Family	**Species**				
Poaceae	*Aciachne pulvinata*	*117*	*14.904459*	7	8.045977
Apiaceae	*Azorella crenata*	*70*	*8.917197*	4	4.597701
Geraniaceae	*Geranium sessiliflorum*	*69*	*8.789809*	4	4.597701
Cyperaceae	*Scirpus rigidus*	*52*	*6.624204*	3	3.448276
Poaceae	*Dactylis glomerata*	*35*	*4.458599*	1	1.149425
Asteraceae	*Misbrookea strigosissima*	*30*	*3.821656*	2	2.298851
Fabaceae	*Lupinus chlorolepis*	*24*	*3.057325*	2	2.298851
Poaceae	*Muhlenbergia ligularis*	*23*	*2.929936*	2	2.298851
Poaceae	*Poa aequigluma*	*22*	*2.802548*	2	2.298851
Polygonaceae	*Rumex acetosella*	*21*	*2.675159*	2	2.298851
Ranunculaceae	*Oreithales integrifolia*	*20*	*2.547771*	1	1.149425
Cyperaceae	*Cyperus sp*	*18*	*2.292994*	1	1.149425
Isoetaceae	*Isoetes lacustris*	*17*	*2.165605*	4	4.597701
Asteraceae	*Hypochaeris taraxacoides*	*17*	*2.165605*	1	1.149425
Asteraceae	*Liabum bullatum*	*17*	*2.165605*	2	2.298851
Gentianaceae	*Gentiana prostrata*	*16*	*2.038217*	1	1.149425
Asteraceae	*Werneria nubígena*	*16*	*2.038217*	3	3.448276
Plantaginaceae	*Plantago rígida*	*15*	*1.910828*	3	3.448276
Asteraceae	*Werneria caespitosa*	*13*	*1.656051*	1	1.149425
Poaceae	*Stipa brachyphylla*	*12*	*1.528662*	2	2.298851
Poaceae	*Calamagrostis spicigera*	*12*	*1.528662*	1	1.149425
Asteraceae	*Werneria humbellata*	*12*	*1.528662*	2	2.298851
Poaceae	*Calamagrostis curvula*	*12*	*1.528662*	1	1.149425
Geraniaceae	*Geranium weddellii*	*10*	*1.273885*	1	1.149425
Asteraceae	*Werneria pinnatifida*	*10*	*1.273885*	3	3.448276
Oxalidaceae	*Oxalis sp*	*10*	*1.273885*	3	3.448276
Ranunculaceae	*Oreithales sp*	*9*	*1.146497*	1	1.149425
Caryophyllaceae	*Arenaria acaulis*	*9*	*1.146497*	1	1.149425
Cyperaceae	*Carex ecuadorica*	*9*	*1.146497*	3	3.448276
Plantaginaceae	*Plantago sp*	*8*	*1.019108*	2	2.298851
Caryophyllaceae	*Paronychia andina*	*8*	*1.019108*	3	3.448276
Asteraceae	*Baccharis tricuneata*	*8*	*1.019108*	1	1.149425
Poaceae	*Calamagrostis vicunarum*	*7*	*0.891720*	2	2.298851
Caryophyllaceae	*Paronychia aretioides*	*7*	*0.891720*	2	2.298851
Poaceae	*Poa candamoana*	*7*	*0.891720*	2	2.298851
Apiaceae	*Azorella compacta*	*5*	*0.636943*	1	1.149425
Rosaceae	*Alchemilla pinnata*	*4*	*0.509554*	4	4.597701
Plantaginaceae	*Plantago tubulosa*	*3*	*0.382166*	1	1.149425
Gentianaceae	*Gentiana sedifolia*	*3*	*0.382166*	1	1.149425
Apiaceae	*Azorella biloba*	*3*	*0.382166*	1	1.149425
Asteraceae	*Gnaphalium supinum*	*3*	*0.382166*	1	1.149425
Cyperaceae	*Eleocharis sp*	*1*	*0.127389*	1	1.149425
Juncaceae	*Luzula racemosa*	*1*	*0.127389*	1	1.149425
	Total	**785**	**100**	**87**	**100**

The most frequent species is Polypogon *interruptus*, representing 13.79% and is frequent in the Tragadero Lagoon. There are several less frequent species, among which are *Lilaeopsis andina, Oxalis sp, Werneria humbellata*, among others, where each species represents 3.45% (Table 2).

Table 2. Floristic composition, abundance and frequency of the Tragadero Lagoon.

Floristic Composition		Absolute Abundance	Relative Abundance (%)	Absolute Frequency	Relative Frequency (%)
Family	**Species**				
Poaceae	*Pennisetum clandestinum*	340	38.461538	4	13.793103
Cyperaceae	*Eleocharis sp*	180	20.361991	2	6.896552
Apiaceae	*Hydrocotile bowlesioides*	102	11.538462	2	6.896552
Cyperaceae	*Eleocharis albi bracteata*	100	11.312217	1	3.448276
Juncaceae	*Juncus arcticus*	37	4.18552	3	10.344828
Rosaceae	*Alchemilla pinnata*	32	3.61991	2	6.896552
Fabaceae	*Medicago hispida*	18	2.036199	3	10.344828
Fabaceae	*Trifolium amabile*	18	2.036199	1	3.448276
Apiaceae	*Lilaeopsis andina*	15	1.696833	1	3.448276
Asteraceae	*Gamochaeta purpurea*	14	1.58371	2	6.896552
Caryophyllaceae	*Paronychia aretioides*	13	1.470588	1	3.448276
Gentianaceae	*Gentianella bellidifolia*	7	0.791855	1	3.448276
Asteraceae	*Taraxacum officinale*	3	0.339367	2	6.896552
Asteraceae	*Werneria humbellata*	2	0.226244	1	3.448276
Oxalidaceae	*Oxalis sp*	1	0.113122	1	3.448276
Poaceae	*Polypogon interruptus*	1	0.113122	1	3.448276
Fabaceae	*Medicago lupulina*	1	0.113122	1	3.448276
	Total	**884**	**100**	**29**	**100**

3.3. Floristic composition, abundance and frequency of the Cucancocha Lagoon

The floristic composition consisted of 19 species identified in the riparian vegetation of the Cucancocha Lagoon, distributed in 7 families. The most representative families are Asteraceae with 7 species and Poaceae with 6 species, followed by Cyperaceae (2), Rosaceae (1), Apiaceae (1), Gentianaceae (1) and Isoetaceae (1).

The most abundant species are *Calamagrostis* sp and *Wernberia humbella*ta, representing 30.48% and 14.74%. The least abundant species are *Passiflora tripartita* and *Podocarpus glomeratus*, which represent 0.11%.

Carex ecuadorica, is the most frequent species, representing 11.33%, being frequent in the Cuicocha Lagoon. There are several less frequent species, among which are *Festuca dolichophylla*, *Taraxacum officinale*, among others, representing 3.33% (Table 3).

3.4. Floristic composition, abundance and frequency of the Incacocha Lagoon

The floristic composition was represented by 22 species identified in the riparian vegetation of the Incacocha Lagoon, distributed in 11 families. The most representative family is Poaceae, with 6 species, followed by Asteraceae (3), Cyperaceae (3), Rosaceae (2), Apiaceae (2), Onagraceae (1), Fabaceae (1), Geraniaceae (1), Caryophyllaceae (1), Valerianaceae (1) and Malvaceae (1).

The most abundant species in the Incacocha lagoon are *Alchemilla pinnata*, and *Festuca humilior*, representing 26.10% and 16.54%. The least abundant species is *Nototriche acaulis*, representing 0.37%, as well as *Lupinus chlorolepis* and *Arenaria acaulis*, among others, where each species represents 0.74%.

The species with greatest frequency is *Alchemilla pinnata*, which represents 11.54%, being frequent in the Incacocha Lagoon. There are several less frequent species, among which are *Oenothera multicaulis*, *Lupinus chlorolepis*, *Baccharis caespitosa*, among others, where each species represents 3.85% (Table 4).

Table 3. Floristic composition, abundance and frequency of the Cucancocha Lagoon.

Floristic Composition		Absolute Abundance	Relative Abundance (%)	Absolute Frequency	Relative Frequency (%)
Family	**Specie**				
Poaceae	*Calamagrostis sp*	153	30.478088	2	6.666667
Asteraceae	*Wernberia umbellata*	74	14.741036	3	10
Cyperaceae	*Carex ecuadorica*	41	8.167331	4	13.333333
Asteraceae	Bella *sp*	41	8.167331	1	3.333333
Poaceae	*Festuca dolichophylla*	36	7.171315	1	3.333333
Poaceae	*Stipa depauperata*	35	6.972112	1	3.333333
Asteraceae	*Hypochaeris taraxacoides*	33	6.573705	2	6.666667
Poaceae	*Calamagrostis vicunarum*	25	4.98008	2	6.666667
Asteraceae	*Paranephelius uniflorus*	20	3.984064	1	3.333333
Rosaceae	*Alchemilla pinnata*	14	2.788845	2	6.666667
Cyperaceae	*Cyperus sp*	12	2.390438	1	3.333333
Gentianaceae	*Gentiana sedifolia*	4	0.796813	2	6.666667
Isoetaceae	*Isoetes lacustris*	4	0.796813	1	3.333333
Asteraceae	*Werneria pygmaea*	3	0.59761	1	3.333333
Poaceae	*Bromus lanatus*	2	0.398406	2	6.666667
Poaceae	*Festuca sp*	2	0.398406	1	3.333333
Asteraceae	*Taraxacum officinale*	1	0.199203	1	3.333333
Asteraceae	*Baccharis tricuneata*	1	0.199203	1	3.333333
Apiaceae	*Oreomyrrhis andicola*	1	0.199203	1	3.333333
Total		**502**	**100**	**30**	**100**

Table 4. Floristic composition, abundance and frequency of the Incacocha Lagoon.

Floristic composition		Absolute abundance	Relative Abundance (%)	Absolute Frequency	Relative Frequency (%)
Family	**Specie**				
Rosaceae	*Alchemilla pinnata*	71	26.102941	3	11.538462
Poaceae	*Festuca humilior*	45	16.544118	2	7.692308
Onagraceae	*Oenothera multicaulis*	25	9.191176	1	3.846154
Apiaceae	*Azorella compacta*	21	7.720588	1	3.846154
Cyperaceae	*Cyperus sp*	20	7.352941	1	3.846154
Poaceae	*Calamagrostis sp*	18	6.617647	1	3.846154
Poaceae	*Muhlenbergia fastigiata*	14	5.147059	1	3.846154
Poaceae	*Stipa brachyphylla*	8	2.941176	1	3.846154
Asteraceae	*Baccharis caespitosa*	7	2.573529	1	3.846154
Poaceae	*Poa aequigluma*	6	2.205882	1	3.846154
Rosaceae	*Alchemilla diplophylla*	5	1.838235	2	7.692308
Poaceae	*Festuca rígida*	5	1.838235	1	3.846154
Valerianaceae	*Valeriana sp*	4	1.470588	1	3.846154
Cyperaceae	*Eleocharis sp*	4	1.470588	1	3.846154
Geraniaceae	*Geranium sessiliflorum*	3	1.102941	1	3.846154
Cyperaceae	*Carex ecuadorica*	3	1.102941	1	3.846154
Apiaceae	*Oreomyrrhis andicola*	3	1.102941	1	3.846154
Asteraceae	Bella *sp*	3	1.102941	1	3.846154
Fabaceae	*Lupinus chlorolepis*	2	0.735294	1	3.846154
Caryophyllaceae	*Arenaria acaulis*	2	0.735294	1	3.846154
Asteraceae	*Werneria humbellata*	2	0.735294	1	3.846154
Malvaceae	*Nototriche acaulis*	1	0.367647	1	3.846154
Total		**272**	**100**	**26**	**100**

3.5. Floristic composition, abundance and frequency of the Ñahuinpuquio lagoon

The floristic composition was represented by 20 identified species in the riparian vegetation of the Ñahuinpuquio Lagoon, distributed in 9 families. The most representative family is Poaceae, with 7 species, followed by Fabaceae (3), Asteraceae (2), Brassicaceae (2), Plantaginaceae (2), Juncaceae (1), Polygonaceae (1), Rosaceae (1) and Apiaceae (1). The most abundant species is *Pennisetum clandestinum*, representing 40.93%. The least abundant species are *Calamagrostis* sp and *Rumex crispus*, where each species represents 0.14%.

The species with greater frequency are *Pennisetum clandestinum*, *Juncus arcticus, Muhlenbergia andina*, among others, where each species represents 8.57% and is frequent in the Ñahuinpuquio Lagoon. There are several less frequent species, among which are *Calamagrostis sp*, *Rumex crispus*, *Cassia sp, Brayopsis calycina* among others, where each species represents 2.86% (Table 5).

Table 5. Floristic composition, abundance and frequency of the Ñahuinpuquio lagoon.

Floristic composition		Absolute abundance	Relative Abundance (%)	Absolute Frequency	Relative Frequency (%)
Family	**Specie**				
Poaceae	*Pennisetum clandestinum*	300	40.927694	3	8.571429
Juncaceae	*Juncus articus*	70	9.549795	3	8.571429
Fabaceae	*Trifolium repens*	48	6.548431	2	5.714286
Plantaginaceae	*Plantago tubulosa*	45	6.139154	2	5.714286
Rosaceae	*Alchemilla pinnata*	38	5.184175	2	5.714286
Fabaceae	*Medicago hispida*	38	5.184175	1	2.857143
Poaceae	*Muhlenbergia andina*	37	5.047749	3	8.571429
Apiaceae	*Hydrocotile bowlesioides*	32	4.365621	1	2.857143
Poaceae	*Muhlenbergia ligularis*	28	3.819918	2	5.714286
Poaceae	*Lolium multiflorum*	21	2.864939	2	5.714286
Plantaginaceae	*Plantago major*	20	2.728513	2	5.714286
Asteraceae	*Bidens andicola*	20	2.728513	1	2.857143
Fabaceae	*Medicago lupulina*	15	2.046385	1	2.857143
Poaceae	*Poa gilgiana*	6	0.818554	2	5.714286
Asteraceae	*Taraxacum officinale*	5	0.682128	2	5.714286
Poaceae	*Polypogon interruptus*	3	0.409277	2	5.714286
Brassicaceae	Bryopsis *calycina*	3	0.409277	1	2.857143
Brassicaceae	*Nasturtium officinale*	2	0.272851	1	2.857143
Poaceae	*Calamagrostis sp*	1	0.136426	1	2.857143
Polygonaceae	*Rumex crispus*	1	0.136426	1	2.857143
Total		**733**	**100**	**35**	**100**

3.6. Analysis of floristic composition

The richness of the local species and the variation of composition among the high Andean wetlands, differ between the types of vegetation; however, the most representative species of the main wetlands of the region make important contributions to the diversity of the landscape (Flinn *et al.*, 2008). Since Pomacocha Lagoon presents the greatest number of species, in the case of the other lagoons the smaller number of species is possibly due to the culture of trout in floating cages (Cucancocha and Incacocha) where pelleted balanced foods are used, which, combined with fish excreta, constitute an important contribution of organic matter to aquatic ecosystems (Mariano *et al.*, 2010) and human activities, mainly tourism (Tragadero and Ñahuinpuquio).

It is estimated that the diversity of plant species and their distribution in space have important effects on the function of wetland ecosystems. We found that wetlands with a greater diversity of type of cover present a greater diversity of plant species than wetlands with less diversity of type of cover. We also found significant relationships between the diversity of plant species and the spatial pattern of cover types, but the direction of the effect differs depending on the measure of diversity used (Brandt *et al.*, 2015).

Condori and Choquehuanca (2001) reported in Puno for Collao Province 45 plant species in high Andean wetlands, presenting a high floristic composition, being similar to the Pomacocha Lagoon; for Tarata 21 plant species were reported, similar respect to the Tragadero, Cucancocha, Incacocha and Ñahuinpuquio Lagoons. In Bolivia, Prieto *et al.* (2001) reported 58 plant species in high Andean wetlands. These results indicate that in the area of influence of our research there is a smaller distribution of species in front of the Bolivian wetland system. This result indicates that in our field of study, there is a lower number of species in wetlands.

Existing studies seem to confirm common generalizations: (1) changes in the type of community of plants across large nutrient gradients; (2) species richness decreases as several indicators of nutrient availability increase beyond a certain threshold; and (3) rare species are almost always associated with species-rich communities (Bedford *et al.*, 1999).

Tovar (1993), cited in Gutiérrez Peralta and Castañeda Sifuentes (2014), mentions that, the Poaceae family is widely distributed in the world; its species are present in all latitudes and altitudes, from sea level to above 5000 m.

Poaceae is one of the families with the highest number of species, with approximately 700 genre and 10,000 species distributed in almost all continents (Clayton and Renvoize, 1986). The Peruvian flora is represented by around 157 genera with 750 species (Brako and Zarucchi, 1993, Ulloa *et al.*, 2004), which are occupying all the bioclimatic levels, from the shores of the Pacific Ocean to the high peaks of the Andes and from these to the Amazon plain crossing the eastern Andes.

Gutiérrez Peralta and Castañeda Sifuentes (2014), for the district of Lircay, report a total of 46 species and one subspecies of the Poaceae family, grouped into 21 genres, 11 tribes and 6 subfamilies. The genus Calamagrostis is the most diverse with 9 species, followed by Poa with 5 species. Also, Aciachne acicularis "paccupaccu", Arundo donax "carrizo", Cortaderia hieronymi and Ortachne erectifolia "iruichu" are new reports for the region of Huancavelica.

Parra Rondinel *et al.* (2004), vegetation and floristic composition of the Pachachaca micro watershed, located in north western Huancavelica, were studied from 2001 to 2003. There were registered 180 species belonging to 57 families. Floristic composition shows a large richness in species. Asteraceae were most representative in the middle and lowland areas, Poaceae in the highlands, and Fabaceae in the middle and lowland areas of the watershed.

Gutiérrez Peralta and Castañeda Sifuentes (2014), a checklist of grasses (Poaceae) from Huancavelica is presented consisting of seven subfamilies, 21 tribes, 74 genres, 255 species, two subspecies, eight varieties, two forms and a hybrid. The checklist consolidates the agrostological flora from the Huancavelica region. Sources range from years of field collections to consultations from Peru herbal.

La Torre *et al.* (2004), recognize 81 endemic species in 19 genres. Peru endemic grasses have been found in practically all recognized ecological regions, although the majority is found in the Dry and Humid Puna, High Andean and Mesoandean regions, from sea level to 5500 m elevation. Twenty-five endemics have been reported to occur in Peru's protected areas.

In a taxonomic study of the Poaceae Family of the Yanachaga-Chemillén National Park and surrounding areas (Oxapampa, Pasco, Peru), 63 Poaceae species were recorded from the subfamilies Pooideae, Centothecoideae, Arundinoideae, Chloridoideae and Panicoideae, which are included in 37 genres and 12 tribes (La Torre *et al.*, 2004).

Gonzáles (2015) reports species of the family Asteraceae registered in wetlands and aquatic systems by floristic inventories made in the high Andean areas of the departments of Ancash, Apurímac, Arequipa, Ayacucho, Cusco, Cajamarca, Huancavelica, Huánuco, Junín, La Libertad, Lima, Moquegua, Pasco, Puno and Tacna, between 2009 and 2015. In this period of time, 200 high Andean wetlands were explored, located in 30 locations, reporting a total of 25 species of the Asteraceae family for the high Andean wetlands. The Asteraceae of the high Andean wetlands are made up solely of herbaceous species and only two species are endemic to Peru, which coincides with the results of the research, since the Asteraceae family is one of the most representative families of the Andean highlands of the Junín region.

In the study, the most abundant species recorded in the lagoons of Pomacocha, Tragadero, Cucancocha, Incacocha and Ñahuinpuquio indicate that they are well adapted to the environment and distributed in the zones of life belonging to the Humid-Montane Tropical Forest (bh-MT) and to the Dry-Montane Low Tropical Forest (bs-MBT) (Alonso *et al.*, 2001), while the low abundance of several species in the aquatic ecosystem, possibly due to the selective use of these species and the presence of anthropogenic activities developed in the area of influence of the study area.

The most frequent species recorded in the five lagoons indicate that these species have characteristics adapted to the environment and are frequent in these wetlands; while the lower frequency of other species in the aquatic ecosystem is possibly due to the exigency of environmental factors (Martino and Zommers, 2007).

To guarantee the long-term conservation of the lentic wetlands (in this case, the high Andean wetlands), it is necessary to develop management and conservation strategies that take into account both natural and created wetlands (Murillo-Pacheco *et al.*, 2016).

3.7. Alpha diversity índices

The results of the investigation show that in the Pomacocha Lagoon species richness (S = 43) indicates that 43 species have been identified in the riparian vegetation; while the Simpson index ($1\text{-}D_{Si}$= 0.9446) indicates that diversity is high.

The Shannon Wiener index (H´= 3.3124) indicates that the diversity in the Pomacocha Lagoon has a high degree of species heterogeneity in plant communities.

In the Tragadero Lagoon, the species richness (S = 17) indicates that 17 species present in the riparian vegetation have been recorded in the study area; while the Simpson index ($1\text{-}D_{Si}$= 0.8227) indicates that diversity is high.

The Shannon Wiener index (H´= 2.2761) indicates that the diversity in the Tragadero Lagoon, has an intermediate degree of heterogeneity of species in the plant communities.

In the Cucancocha Lagoon, the richness of species (S = 19) indicates that 19 species have been identified in the riparian vegetation; while the Simpson index ($1\text{-}D_{Si}$= 0.8521) indicates that diversity is high.

The Shannon Wiener index ((H´= 2.2628) indicates that the diversity in the Cucancocha Lagoon has an intermediate degree of heterogeneity of species in plant communities.

In the Incacocha Lagoon, the species richness (S = 22) indicates that 22 species have been recorded in the riparian vegetation; while the Simpson index ($1\text{-}D_{Si}$= 0.8739) indicates that diversity is high.

The Shannon Wiener index (H´= 2.4706) indicates that the diversity in the Incacocha Lagoon has an intermediate degree of species heterogeneity in plant communities.

In the Ñahuinpuquio Lagoon, the richness of species (S = 20) indicates that 20 species present in the riparian vegetation have been identified, while the Simpson index ($1\text{-}D_{Si}$= 0.8011) indicates that the diversity is high.

The Shannon Wiener index (H´= 2.1891) indicates that the diversity in the Ñahuinpuquio lagoon has an intermediate degree of heterogeneity of species in the plant communities (Table 6).

Table 6. Alpha diversity indices in high Andean wetlands of the Junín region.

Indicators of Diversity	Lagoons				
	Pomacocha	Tragadero	Cucancocha	Incacocha	Ñahuinpuquio
Wealth of species (S)	43	17	19	22	20
Simpson Index ($1\text{-}D_{Si}$)	0.9446	0.8227	0.8521	0.8739	0.8011
Shannon-Wiener Index (H’)	3.3124	2.2761	2.2628	2.4706	2.1891

Yaranga *et al.* (2018), in the study of the Floristic diversity in grasslands according to plant formation in the Shullcas River subwatershed, Junin, Peru reports that the Shannon-Wiener index (H ') revealed that plant formations in the upper part have a high diversity of 3.12 to 3.41; while in the lower part they have an average diversity of 2.75 and 2.81. These results are close to that found in the páramos by Caranqui *et al.* (2016), which coincides with the highest H 'value in the case of grasslands with greater coverage (Zheng *et al.*, 2014). This fact reaffirms the theory that grassland ecosystems present heterogeneous diversity with the presence of different species among them (Habel *et al.*, 2013); this indicates that the location of the plots evaluated in each plant formation influences the obtained index (Janišová *et al.*, 2013).

The comparison of these indices with those obtained by other authors is difficult, due to the differences in the methods and sampling areas within the wetland. Therefore, it is necessary to establish the base elements and the conditions under which the indices must be calculated, so that aspects such as area and sampling area, habit (arboreal, shrub, herbaceous) and size categories, which allow comparisons between similar ecosystems (Cantillo *et al.*, 2004 cited in González-Pinto, 2017).

Alpha diversity indices are very useful in the description of ecological communities. Given that diversity in a community is an expression of the distribution of resources and energy, its study is one of the most useful approaches in the analysis of communities (Carranza, 2002).

Regarding the Wealth of Species (S) Carranza (2002) mentions that, the ideal form of measurement, it is to have a complete inventory that allows us to know the total number of species, obtained by a census of the community; however, in the research this index has been determined from a sampling of the riparian vegetation communities of the five high Andean lagoons, based solely on the number of species present in the study area.

The results of the biodiversity indices indicate that the diversity of riparian vegetation in the Pomacocha, Tragadero, Cucancocha, Incacocha and Ñahuinpuquio Lagoons present a low level of alteration, due to the different anthropogenic activities developed in the area of influence (livestock, fish farming, tourism); However, the Pomacocha Lagoon presents better indices of diversity, since in this aquatic ecosystem the anthropogenic activities are smaller. It is therefore necessary to consider the statements made by Peralta-Peláez *et al.* (2009), who indicate that management plans should be developed together with the communities that allow the use of these high Andean lagoons but that at the same time guarantee the permanence of the composition and structure of the riparian vegetation characteristic of these aquatic ecosystems.

4. CONCLUSIONS

Floristic composition, abundance and frequency, indicate that the most representative families of the Pomacocha Lagoon are Poaceae and Asteraceae, of Tragadero are Asteraceae and Fabaceae, of Cucancocha are Asteraceae and Poaceae, and of Incacocha and Ñahuinpuquio is Poaceae. The values of species richness indices, Simpson and Shannon-Wiener, indicate that the diversity of riparian vegetation of aquatic ecosystems still present a low level of alteration due to the different anthropogenic activities developed in the area of influence.

The use of these high Andean lagoons, through the development of management plans together with the communities, will guarantee the permanence of the composition and structure of the riparian vegetation characteristic of these aquatic ecosystems.

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